

## COMMERCIAL MODULE TEST PROGRAM

JET PROPULSION LABORATORY

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### Purpose

- Investigate state of the art of module design and manufacture
- Identify problems requiring additional research

### Approach

- Obtain commercial PV modules in current production
- Perform Block V Qualification Tests
- Perform failure analysis
- Obtain modules with defects corrected
- Repeat qualification tests

### Module Manufacturers

<b>AEG Telefunken</b>	<b>West Germany</b>
<b>Helios</b>	<b>Italy</b>
<b>Photowatt</b>	<b>France</b>
<b>Hoxan</b>	<b>Japan</b>
<b>Kyocera</b>	<b>Japan</b>
<b>Siemens</b>	<b>West Germany</b>
<b>Solavolt</b>	<b>USA</b>
<b>Solec</b>	<b>USA</b>
<b>Toyomenka</b>	<b>Japan</b>



# MODULE AND RELIABILITY TECHNOLOGY

## Efficiency Comparisons

Module Manufacturer	Power, Module (W)	Efficiency, Module (%)	Efficiency, Encapsulated Cell (%)	Efficiency, Module, at 0.9 Packing Factor (%)
<b>Single-YTL Cells</b>				
Helios	41.7	9.4	11.6	10.4
Hoxan	37.5	9.3	13.9	12.5
Siemens	130.8	8.7	11.6	10.4
Toyomenka	40.3	10.5	11.7	10.5
<b>Semi-XTL Cells</b>				
AEG Telefunken	38.7	7.9	9.8	8.8
Photowatt	36.1	7.5	10.0	9.0
Kyocera	42.8	9.8	12.0	10.8
Solavolt	38.6	8.4	10.6	9.5
Solec	40.3	10.5	11.7	10.5

The above data are based on JPL power measurements of one sample of the type module obtained for qualification testing and on nominal dimensions of module and cell areas.

## Module Description Manufacturer: Helios, Italy

### Mechanical

#### Dimensions

Module: 131 cm x 34.0 cm

Cell: 10.0 cm<sup>2</sup>

Packing factor: 0.81

#### Materials

Cells: Single XTL Silicon

Superstrate: Tempered glass

Encapsulant: EVA

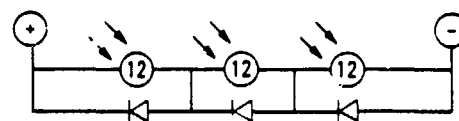
Back cover: Tedlar

Edge seal: Silicon rubber

Frame: Aluminum

### Electrical

#### CIRCUIT



#### Sample Performance (Standard Conditions)

Power, max: 41.7 W

Voltage: 15.8 V

Current: 2.64 A

V<sub>oc</sub>: 20.2 V

I<sub>sc</sub>: 3.02 A

η, module: 9.4%

η, encapsulated cell: 11.6%

MODULE AND RELIABILITY TECHNOLOGY

Photovoltaic Module (Top View)  
Manufacturer: Helios, Italy

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Photovoltaic module (Bottom View)  
Manufacturer: Helios, Italy



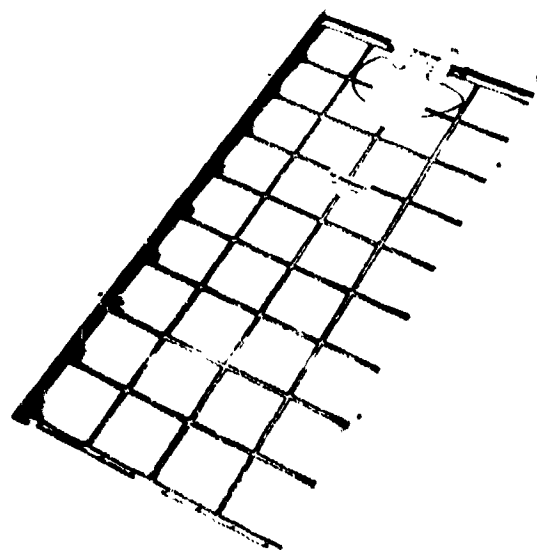
MODULE AND RELIABILITY TECHNOLOGY

Photovoltaic Module (Top View)  
Manufacturer: Photowatt, France

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Photovoltaic Module (Bottom View)  
Manufacturer: Photowatt, France



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## MODULE AND RELIABILITY TECHNOLOGY

### Module Description Manufacturer: Photowatt, France

#### Mechanical

##### Dimensions

Module: 104.3 cm x 46.2 cm

Cell: 10.0 cm<sup>2</sup>

Packing factor: 0.75

##### Materials

Cells: Semi XTL Silicon

Substrate: Tempered glass

Encapsulant: PVB

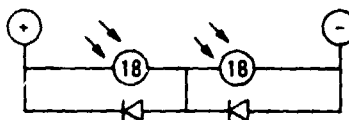
Back cover: Tempered glass

Edge seal: Silicon rubber

Frame: Aluminum

#### Electrical

##### CIRCUIT



##### Standard Conditions)

Power, max: 36.1 W

Voltage: 16.3 V

Current: 2.22 A

V<sub>oc</sub>: 20.1 V

I<sub>sc</sub>: 2.46 A

$\eta$ , module: 7.5%

$\eta$ , encapsulated cell: 10.0%

### Module Description Manufacturer: Siemens, West Germany

#### Mechanical

##### Dimensions

Module: 146.9 cm x 102 cm

Cell: 10.0 cm diameter

Packing factor: 0.75

##### Materials

Cells: Single XTL Silicon

Superstrate: Tempered glass

Encapsulant: PVB

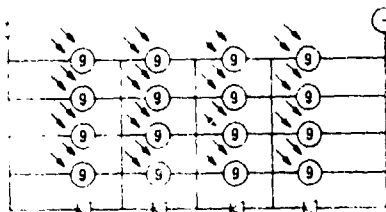
Back cover: Tedlar/Al/Tedlar

Edge seal: Foil tape/rubber

Frame: Aluminum

#### Electrical

##### CIRCUIT



##### Sample Performance (Standard Conditions)

Power, max: 130.8 W

Voltage: 16.5 V

Current: 7.91 A

V<sub>oc</sub>: 21.3 V

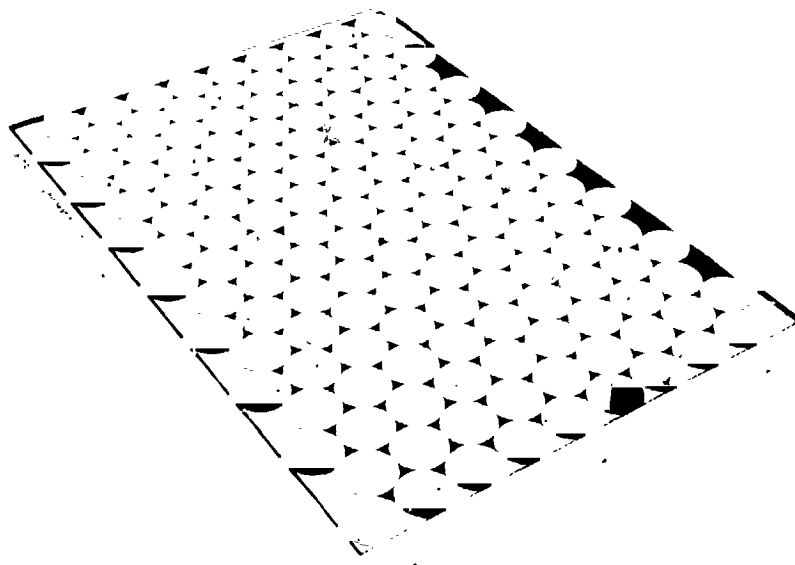
I<sub>sc</sub>: 8.76 A

$\eta$ , module: 8.7%

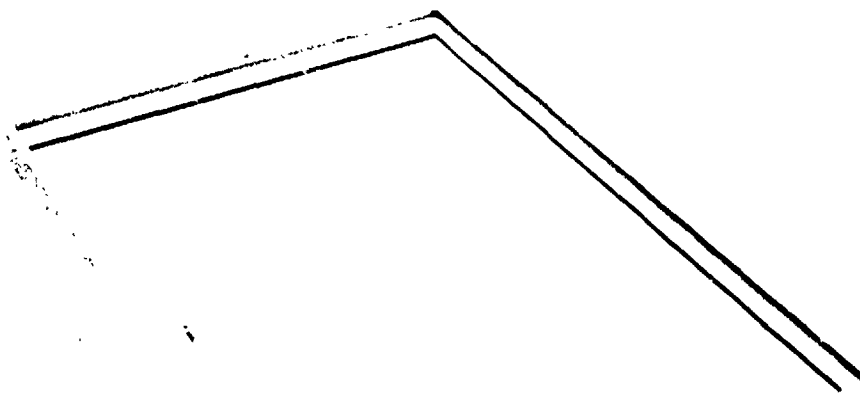
$\eta$ , encapsulated cell: 11.6%

## MODULE AND RELIABILITY TECHNOLOGY

**Photovoltaic Module (Top View)**  
**Manufacturer: Siemens, West Germany**



**Photovoltaic Module (Bottom View)**  
**Manufacturer: Siemens, West Germany**



## MODULE AND RELIABILITY TECHNOLOGY

### Qualification Test Record

<b>Module Designs Tested</b>	<b>12</b>
<b>Number Passed</b>	<b>6</b>
<b>Number Failed</b>	<b>6</b>

### Failure Record

Test	Failed Designs	Failure Mode
T-50	1	Cracked interconnects. Power down
	1	Cracked cells. Power down
T-200	1	Encapsulant delamination
MI-10K	1	Cracked interconnects. Power down
Hot-Spot	2	Blistered Tedlar. Burn marks on Tedlar and encapsulant

### Conclusions

- Most commercial modules use Block V technology
- Most commercial module designs do not pass the Block V Qualification Tests at the first attempt. (The Project phaseout plan precluded correction of defects and repetition of tests for the designs that failed)
- Semi-crystalline cell modules with one bypass diode per 36 series cells may pass the Hot-Spot test, but cell temperatures reach 150°C
- Although the precise cause of the cell cracks that caused power degradation was not determined, it seems clear that excess degradation would not have occurred if Block V (failure tolerant) cell/interconnect designs had been used
- It could not be determined whether the interconnect failures were caused by hitherto unexpected causes; failure analysis was terminated because of funding limitations
- The Block V Qualification Tests have again demonstrated their effective role in the development of reliable modules